Advanced Placement Examination

PHYSICS 1

SECTION I

TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS

Proton mass,	$m_p = 1.67 \times 10^{-27}$ kg
Neutron mass,	$m_n = 1.67 \times 10^{-27}$ kg
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg
Electron charge magitude,	$e = 1.60 \times 10^{-19}$ C
Universal gravitational constant,	$G = 6.67 \times 10^{-11}$ $m^3/kg \cdot s^2$

PREFIXES

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

UNITS

Name	Symbol
meter	m
kilogram	kg
second	s
ampere	A
joule	J
watt	W
coulomb	C
volt	V
ohm	Ω

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	$\sin\theta$	$\cos\theta$	$\tan\theta$
0°	0	1	0
30°	1/2	$\sqrt{3}/2$	$\sqrt{3}/3$
37°	3/5	4/5	3/4
45°	$\sqrt{2}/2$	$\sqrt{2}/2$	1
53°	4/5	3/5	4/3
60°	$\sqrt{3}/2$	1/2	$\sqrt{3}$
90°	1	0	∞

The following conventions are used in this examination.

I. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.

II. The direction of any electric current is the direction of flow of positive charge (conventional current).

III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.

IV. For mechanics and thermodynamics equations, *W* represents the work done on a system.

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AP PHYSICS 1

SECTION I

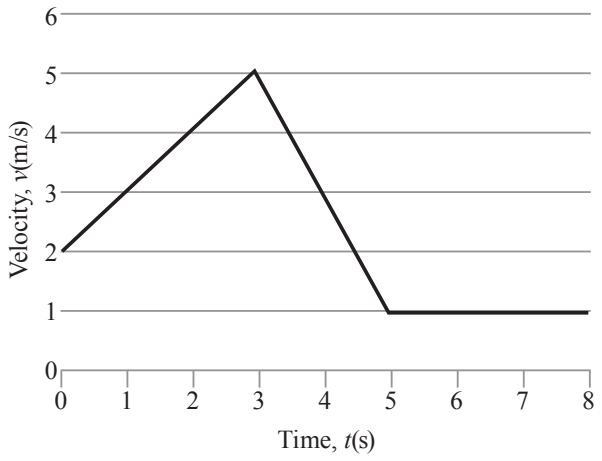
Note: To simplify calculations, you may use $g = 10$ m/s^2 in all problems.

Directions: Each of the questions or incomplete statements is followed by four suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

1. An object is thrown horizontally off a high cliff at 7.5 m/s (assume altitude near sea level and neglect air resistance). What is its displacement after 2 seconds?

   (A) 27.5 m
   (B) 25 m
   (C) 20 m
   (D) 15 m

Questions 2-3 refer to the following figure:



2. What is the object's acceleration during the interval $t = 0$ s to $t = 3$ s?

   (A) 0.5 m/s^2
   (B) 1 m/s^2
   (C) 1.5 m/s^2
   (D) 2 m/s^2

3. What is the distance an object covers during the interval $t = 0$ s to $t = 5$ s?

   (A) 25 m
   (B) 16.5 m
   (C) 15 m
   (D) 8.5 m

4. A ball is thrown in a projectile motion trajectory with an initial velocity v at an angle θ above the ground. If the acceleration due to gravity is $-g$, which of the following is the correct expression of the time it takes for the ball to reach its highest point, y, from the ground?

   (A) $v^2 \sin t / g$
   (B) $-v \cos \theta / g$
   (C) $v \sin \theta / g$
   (D) $v^2 \cos \theta / g$

5. A bubble in a glass of water releases from rest at the bottom of the glass and rises at acceleration a to the surface in t seconds. How much farther does the bubble travel in its last second than in its first second?

   (A) at
   (B) $(t - 1)a$
   (C) $(t + 1)a$
   (D) $\frac{1}{2}at$

6. An object is thrown with an initial speed of 7 m/s directed 45° above the horizontal from a cliff. After reaching the peak of its trajectory, it falls 20 m to the ground below. What is the approximate ratio of the time it takes to hit the ground from the peak of the trajectory to the time it takes from its release to the peak of the trajectory.

   (A) 0.5
   (B) 1
   (C) 2
   (D) 4

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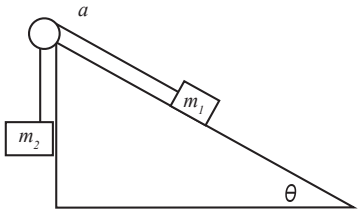
7. A person standing on a horizontal floor is acted upon by two forces: the downward pull of gravity and the upward normal force of the floor. These two forces
   (A) have equal magnitudes and form an action-reaction pair
   (B) have equal magnitudes and do not form an action-reaction pair
   (C) have unequal magnitudes and form an action-reaction pair
   (D) have unequal magnitudes and do not form an action-reaction pair

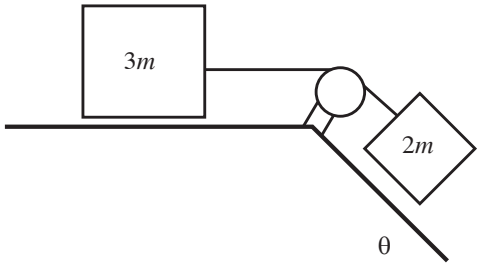
8. A 50 kg block resting on flat ground is attached by a hook at the center of its top face to a rope, which is then pulled by a man such that it makes an angle of 30° with the horizontal. If the man pulls with a force of 200 N and the coefficient of kinetic friction between the block and the ground is 0.2, what horizontal acceleration does the block undergo?
   (A) 3.2 m/s^2
   (B) 2.8 m/s^2
   (C) 1.8 m/s^2
   (D) 1.4 m/s^2

9. A satellite weighs 10^4 N at ground control. What best approximates the acceleration it experiences in orbit at an altitude of twice the earth's radius?
   (A) 111 m/s^2
   (B) 2.5 m/s^2
   (C) 2 m/s^2
   (D) 1.1 m/s^2



10. Consider the above configuration of masses attached via a massless rope and pulley over a frictionless inclined plane. What is the acceleration of the masses?
   (A) $(m_1 - m_2)\, g / (m_1 + m_2)$
   (B) $(m_1 - m_2 \sin\theta)\, g / (m_1 + m_2)$
   (C) $(m_1 - m_2 \cos\theta)\, g / (m_1 + m_2)$
   (D) g

11. A person is pulling a block of mass m with a force equal to its weight directed 30° above the horizontal plane across a rough surface, generating a friction f on the block. If the person is now pushing downward on the block with the same force 30° above the horizontal plane across the same rough surface, what is the friction on the block? (μ_k is the coefficient of kinetic friction across the surface.)
   (A) f
   (B) $1.5f$
   (C) $2f$
   (D) $3f$



12. In the figure above, are two blocks of mass $3m$ and $2m$ attached together. The plane is frictionless and the pulley is frictionless and massless. The inclined portion of the plane creates an angle θ with the horizontal floor. What is the acceleration of the block $2m$ if both blocks are released from rest (gravity = g)?
   (A) $2mg$
   (B) $\left(\frac{2}{5}\right) g \sin\theta$
   (C) $\left(\frac{2}{3}\right) g \sin\theta$
   (D) $\left(\frac{3}{5}\right) g \sin\theta$

13. A rope of length 60 cm is tied to the handle of a bucket (whose mass is 3 kg), and the bucket is then whirled in a vertical circle. At the bottom of its path, the tension in the rope is 50 N. What is the speed of the bucket at this point?
   (A) 1 m/s
   (B) 2 m/s
   (C) 3 m/s
   (D) 4 m/s

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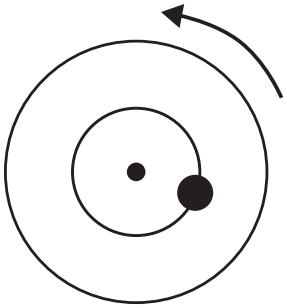
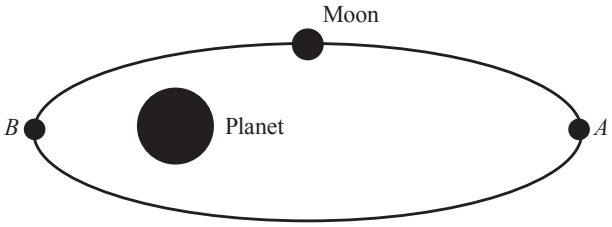


14. The diagram above shows a top view of an object of mass M on a circular platform of mass $2M$ that is rotating counterclockwise. Assume the platform rotates without friction. Which of the following best describes an action by the object that will increase the angular speed of the entire system?

    (A) The object moves toward the center of the platform, increasing the total angular momentum of the system.
    (B) The object moves toward the center of the platform, decreasing the rotational inertia of the system.
    (C) The object moves away from the center of the platform, increasing the total angular momentum of the system.
    (D) The object moves away from the center of the platform, decreasing the rotational inertia of the system.



15. A moon has an elliptical orbit about the planet as shown above. At point A the moon has speed v_A and is at a distance r_A from the planet. At point B, the moon has a speed of v_B. Which of the following correctly explains the method for determining the distance of the moon from the planet at point B in the given quantities?

    (A) Conservation of angular momentum, because the gravitational force exerted by the moon on the planet is the same as that exerted by the planet on the moon.
    (B) Conservation of angular momentum, because the gravitational force exerted on the moon is always directed towards the planet.
    (C) Conservation of energy, because the gravitational force exerted on the moon is always directed towards the planet.
    (D) Conservation of energy, because the gravitational force exerted by the moon on the planet is the same as that exerted by the planet on the moon.

16. A sphere starts from rest atop a hill with a constant angle of inclination and is allowed to roll without slipping down the hill. What force provides the torque that causes the sphere to rotate?

    (A) Static friction
    (B) Kinetic friction
    (C) The normal force of the hill on the sphere
    (D) Gravity

17. A 1000 kg object is hung on a string in between two identical towers that are 340 m apart. The object sits 100 m below the height of the towers. What is the tension in the string?

    (A) 5 kN
    (B) 8 kN
    (C) 10 kN
    (D) 20 kN

18. Which of the following concerning uniform circular motion is true?

    (A) The centrifugal force is the action-reaction pair of the centripetal force.
    (B) The centripetal acceleration and velocity point in the same direction.
    (C) The velocity of the object in motion changes whereas the acceleration of the object is constant.
    (D) An satellite undergoing uniform circular motion is falling towards the center in a circular path.

19. Two objects are sitting on a uniform stick that pivots around its center. Object 1 has a mass of 20 kg and Object 2 has a mass of 30 kg. If the Object 2 sits 1m to the left of the center of the stick, how far to the right of the center of the stick must Object 1 sit in order to balance the stick?

    (A) 0.25 m
    (B) 0.5 m
    (C) 1 m
    (D) 1.5 m

20. The Sun is approximately 150 million kilometers from the Earth. A year—the time for one revolution of the earth around the Sun—is roughly $\pi \times 10^7$ seconds. Assuming a circular orbit, what best approximates the average acceleration of the Earth due to the sun?

    (A) 6×10^{-6} m/s^2
    (B) 6×10^{-3} m/s^2
    (C) 4×10^{2} m/s^2
    (D) 4×10^{19} m/s^2

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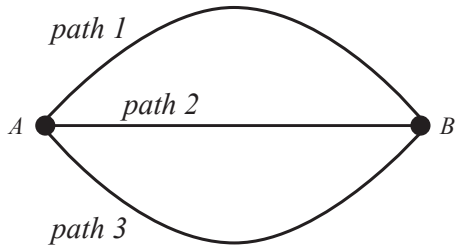
21. A rectangular book weighing 20 N with sides of 10 cm and 20 cm is placed on a horizontal table.

    Using each of your hands, you exert forces of 10 N each in opposite directions at opposite corners, such that you are pushing parallel to the shorter side in each case. What net torque are you providing to the book?

    (A) 0 N·m
    (B) 0.5 N·m
    (C) 1 N·m
    (D) 2 N·m

22. Two objects, a sphere and a block of the same mass, are released from rest at the top of an inclined plane. The sphere rolls down the inclined plane without slipping. The block slides down the plane without friction. Which object reaches the bottom of the ramp first?

    (A) The sphere, because it gains rotational kinetic energy, but the block does not
    (B) The sphere, because it gains mechanical energy due to the torque exerted on it, but the block does not
    (C) The block, because it does not lose mechanical energy due to friction, but the sphere does
    (D) The block, because it does not gain rotational kinetic energy, but the sphere does



23. In the diagram above, a mass m starting at point A is projected with the same initial horizontal velocity v_0 along each of the three tracks shown here (with negligible friction) sufficient in each case to allow the mass to reach the end of the track at point B. (Path 1 is directed up, path 2 is directed horizontal, and path 3 is directed down.) The masses remain in contact with the tracks throughout their motions. The displacement A to B is the same in each case, and the total path length of path 1 and 3 are equal. If t_1, t_2, and t_3 are the total travel times between A and B for paths 1, 2, and 3, respectively, what is the relation among these times?

    (A) $t_3 < t_2 < t_1$
    (B) $t_2 < t_3 < t_1$
    (C) $t_2 < t_1 = t_3$
    (D) $t_2 = t_3 < t_1$

24. An object of mass m (Object 1) moving with speed v collides head-on with a target object of mass $2m$ (Object 2) initially at rest. If the collision is perfectly inelastic, what fraction of Object 1's initial kinetic energy is lost?

    (A) $\frac{1}{9}$
    (B) $\frac{1}{6}$
    (C) $\frac{2}{3}$
    (D) $\frac{4}{5}$

25. The gravitational force the Sun exerts on the Earth is F. Mars is 1.5 times from the Sun than the Earth and its mass is $\frac{1}{6}$ of the Earth's mass. What is the gravitational force that the Sun exerts on Mars?

    (A) $\frac{2}{27}$ F
    (B) $\frac{1}{9}$ F
    (C) 9 F
    (D) $\frac{27}{2}$ F

26. A box of mass m is sitting on an incline of 45° and it requires an applied force F up the incline to get the box to begin to move. What is the maximum coefficient of static friction?

    (A) $\left(\frac{\sqrt{2}F}{mg}\right) - 1$
    (B) $\left(\frac{\sqrt{2}F}{mg}\right)$
    (C) $\left(\frac{\sqrt{2}F}{mg}\right) + 1$
    (D) $\left(\frac{2F}{mg}\right) - 1$

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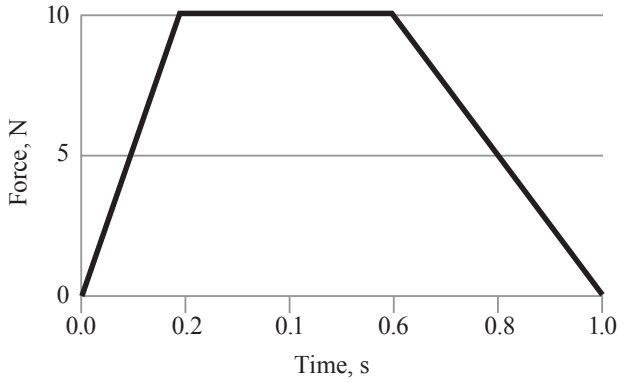
27. Object 1 of mass 0.25 kg moves at 10 m/s towards Object 2 initially at rest of mass 0.25 kg. The resulting collision is perfectly inelastic, what is the speed of the objects after the collision?

(A) 0 m/s
(B) 2.5 m/s
(C) 5 m/s
(D) 7.5 m/s

Questions 28-29 refer to the following figure:



The graph above shows a force F acting on an object of mass $m = 1$ kg.

28. What is the magnitude of the impulse on the force?

(A) 10 N·s
(B) 7 N·s
(C) 5 N·s
(D) 1 N·s

29. If the object's initial velocity is 2 m/s, what will be the object's velocity after this force acts upon the object?

(A) 12 m/s
(B) 10 m/s
(C) 9 m/s
(D) 6 m/s

30. An object of mass 3 kg is undergoing uniform circular motion. The object's speed is 4 m/s, and the radius of the path is 0.5 m. How much work is done on this object by the centripetal force?

(A) 50 J
(B) 12 J
(C) 6 J
(D) 0 J

31. A sound wave with frequency f travels through air at speed v. With what speed will a sound wave with frequency $4f$ travel through the air?

(A) $v/4$
(B) v
(C) $2v$
(D) $4v$

32. An object has a kinetic energy of K. If the speed of the object were doubled what would be the resulting kinetic energy?

(A) $\frac{1}{2}K$
(B) K
(C) $2K$
(D) $4K$

33. An object of 100 kg rests on a horizontal floor. The coefficient of static friction is $\mu_s = 0.4$ between the object and the floor. If a constant force of 250 N is pushed horizontally on the object, what is the magnitude of the force of static friction?

(A) 400 N
(B) 350 N
(C) 250 N
(D) 150 N

34. An object begins at rest at the top of an inclined frictionless plane with a height of 125 m and horizontal length (not the hypotenuse) of 200 m. What will be the speed of the object at the end of the inclined plane?

(A) 235 m/s
(B) 100 m/s
(C) 50 m/s
(D) 23.5 m/s

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35. A 4 kg wooden block resting on an icy surface (so friction can be ignored) is attached to a horizontal spring (L = 1 m, k = 100 N/m), which is attached on the other end to a vertical wall. A 2 g bullet is fired at a speed of 100 m/s into the wooden block, pushing it directly toward the wall. Which of the following best approximates the period and amplitude of the resulting oscillations?

(A) T = 1.2 s, A = 45 cm
(B) T = 1.2 s, A = 1 cm
(C) T = 0.83 s, A = 45 cm
(D) T = 0.83 s, A = 21 cm

36. A 100 kg object is attached to a spring mounted to the ceiling with a spring coefficient of k = 100 N/m. If the spring is stretched by 30 m from the initial resting position with the block attached, what is it's acceleration at that point?

(A) 0 m/s^2
(B) 10 m/s^2
(C) 20 m/s^2
(D) 30 m/s^2

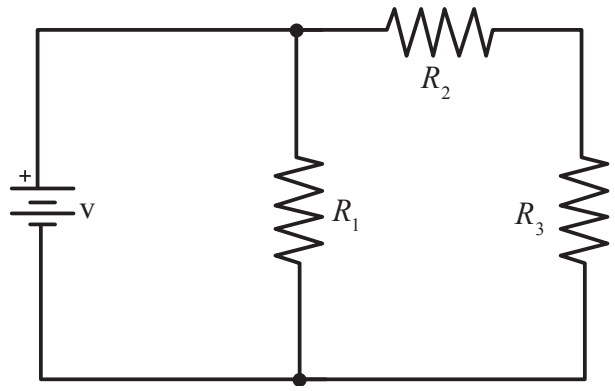
37. A pair of protective headphones reduces the sound of a jet engine from 140 dB to 110 dB. What percent of the noise is being blocked?

(A) 99.9%
(B) 78.6%
(C) 21.4%
(D) 0.1%

38. You are standing on a railroad track as a train approaches at a constant velocity. Suddenly the engineer sees you, applies the brakes, and sounds the whistle. Which of the following describes the sound of the whistle as you hear it starting from that moment?

(A) Loudness increasing, pitch increasing
(B) Loudness increasing, pitch constant
(C) Loudness decreasing, pitch increasing
(D) Loudness increasing, pitch decreasing

Questions 39-41 refer to the following figure:



39. Determine the total power dissipated through the circuit shown above in terms of V, R_1, R_2, and R_3.

(A) $\dfrac{V^2}{R_1 + R_2 + R_3}$

(B) $\dfrac{R_1 + R_2 + R_3}{V^2}$

(C) $\dfrac{R_1(R_2 + R_3)}{V^2(R_1 + R_2 + R_3)}$

(D) $\dfrac{V^2(R_1 + R_2 + R_3)}{R_1(R_2 + R_3)}$

40. If V = 100 V, R_1 = 50 Ω, R_2 = 80 Ω and R_3 = 120 Ω. Determine the voltage across R_3.

(A) 100 V
(B) 60 V
(C) 40 V
(D) 20 V

41. If R_1 were to burn out, the current coming out from the battery would

(A) increase
(B) decrease
(C) stay the same
(D) there is no current, because the circuit is now incomplete

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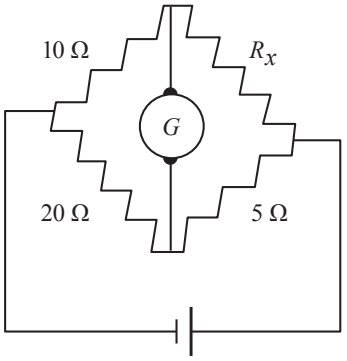
42. Wire #1 has three times the length and twice the diameter of Wire #2. If both wires are made of the same material and if R_1 is the resistance of Wire #1 and R_2 is the resistance of Wire #2, then which of the following is true?

(A) $R_2 = \left(\frac{2}{3}\right) R_1$

(B) $R_2 = \left(\frac{4}{3}\right) R_1$

(C) $R_2 = 6R_1$

(D) $R_2 = 12R_1$



43. A Wheatstone bridge (diagram above) is a configuration of resistors and a sensitive current meter, called a *galvanometer*, that is used to determine the resistance of an unknown resistor. In the Wheatstone bridge shown here, find the value of R_x such that the current through galvanometer G is zero.

(A) 25
(B) 15
(C) 10
(D) 2.5

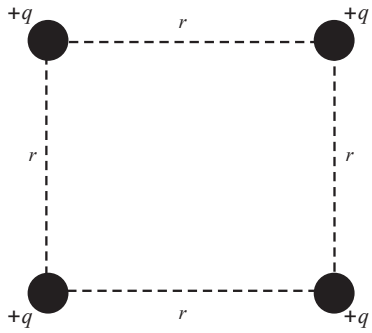
44. Two equally positive charges are r distance apart. If the amount of charge on one is doubled and the distance between the charges is doubled, what is the ratio of new electric force to old electric force?

(A) $\frac{1}{4}$

(B) $\frac{1}{2}$

(C) 2

(D) 4



45. In the figure above, four charges are arranged. If the magnitudes of all the charges q are all the same and the distance r between them is as shown above, what is the magnitude of the net force on the bottom right charge in terms of q, r, and k (where $k = \frac{1}{4\pi\varepsilon_0}$)?

(A) $k\left(\frac{q^2}{2r^2}\right)(1+\sqrt{2})$

(B) $k\left(\frac{q^2}{r^2}\right)(1+\sqrt{2})$

(C) $k\left(\frac{q^2}{2r^2}\right)$

(D) $k\left(\frac{q^2}{r^2}\right)$

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Directions: For each of the questions 46-50, two of the suggested answers will be correct. Select the two answers that are best in each case, and then fill in both of the corresponding circles on the answer sheet.

46. An object traveling at x m/s can stop at a distance d m with a maximum negative acceleration. If the car is traveling at $2x$ m/s, which of the following statements are true? Select two answers.
    (A) The stopping time is doubled
    (B) The stopping time is quadrupled
    (C) The stopping distance is doubled
    (D) The stopping distance is quadrupled

47. A 2 kg mass is attached to a massless, 0.5 m string and is used as a simple pendulum by extending it to an angle $\theta = 5°$ and allowing it to oscillate. Which of the following changes will change the period of the pendulum? Select two answers.
    (A) Replacing the mass with a 1 kg mass
    (B) Changing the initial extension of the pendulum to a 10° angle
    (C) Replacing the string with a 0.25 m string
    (D) Moving the pendulum to the surface of the Moon

48. N resistors ($N > 2$) are connected in parallel with a battery of voltage V_o. If one of the resistors is removed from the circuit, which of the following quantities will decrease? Select two answers.
    (A) The voltage across any of the remaining resistors
    (B) The current output by the battery
    (C) The total power dissipated in the circuit
    (D) The voltage supplied by the battery

49. Which of the following statements will increase the resistance of a closed circuit system? Select two answers.
    (A) Replacing the wire with one that has a smaller cross section area
    (B) Adding a voltmeter to the wire
    (C) Halving the wire length in the close circuit
    (D) Adding another resistor in parallel with the current resistor in a closed circuit

50. A sound wave travels through a metal rod with wavelength λ and frequency f. Which of the following is true? Select two answers.
    (A) When this sound wave passes into air, the frequency will change
    (B) When this sound wave passes into air, the wavelength will change
    (C) While in the metal rod, the λ and frequency f have a direct relationship
    (D) While in the metal rod, the λ and frequency f have an inverse relationship

END OF SECTION I

PHYSICS 1

SECTION II

Free-Response Questions

Time—90 minutes

Percent of total grade—50

General Instructions

Use a separate piece of paper to answer these questions. Show your work. Be sure to write CLEARLY and LEGIBLY. If you make an error, you may save time by crossing it out rather than trying to erase it.

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ADVANCED PLACEMENT PHYSICS 1 EQUATIONS

NEWTONIAN MECHANICS

$v = v_0 + at$

$x = x_0 + v_0 t + \frac{1}{2}at^2$

$v^2 = v_0^2 + 2a(x - x_0)$

$\Sigma \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$

$F_{fric} \leq \mu N$

$a_c = \frac{v^2}{r}$

$\tau = rF \sin\theta$

$\mathbf{p} = m\mathbf{v}$

$\mathbf{J} = \mathbf{F}\Delta t = \Delta\mathbf{p}$

$K = \frac{1}{2}mv^2$

$\Delta U_g = mgh$

$W = F\Delta r \cos\theta$

$P_{avg} = \frac{W}{\Delta t}$

$P = Fv\cos\theta$

$\mathbf{F}_s = -k\mathbf{x}$

$U_s = \frac{1}{2}kx^2$

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

$T = \frac{1}{f}$

$F_G = -\frac{Gm_1m_2}{r^2}$

$U_G = -\frac{Gm_1m_2}{r}$

a = acceleration
F = force
f = frequency
h = height
J = impulse
K = kinetic energy
k = spring constant
ℓ = length
m = mass
N = normal force
P = power
p = momentum
r = radius or distance
T = period
t = time
U = potential energy
v = velocity or speed
W = work done on a system
x = position
μ = coefficient of friction
θ = angle
τ = torque

ELECTRICITY AND MAGNETISM

$F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$

$\mathbf{E} = \frac{\mathbf{F}}{q}$

$I_{avg} = \frac{\Delta Q}{\Delta t}$

$R = \frac{\rho\ell}{A}$

$V = IR$

$P = IV$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
$\mathcal{E}$ = emf
F = force
I = current
ℓ = length
P = power
Q = charge
q = point charge
R = resistance
r = distance
t = time
U = potential (stored) energy
V = electric potential or potential difference
v = velocity or speed
ρ = resistivity
θ = angle
ϕ_m = magnetic flux

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ADVANCED PLACEMENT PHYSICS 1 EQUATIONS

GEOMETRY AND TRIGONOMETRY

Rectangle

$A = bh$

Triangle

$A = \frac{1}{2}bh$

Circle

$A = \pi r^2$

$C = 2\pi r$

Parallelepiped

$V = \ell wh$

Cylinder

$V = \pi r^2 \ell$

$S = 2\pi r\ell + 2\pi r^2$

Sphere

$V = \frac{4}{3}\pi r^3$

$S = 4\pi r^2$

Right Triangle

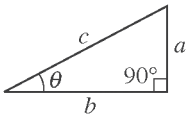
$a^2 + b^2 = c^2$

$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$

A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius



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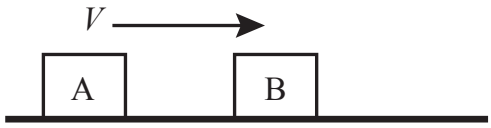
AP PHYSICS 1

SECTION II

Directions: Questions 1, 2, and 3 are short free-response questions that require about 13 minutes to answer and are worth 8 points. Questions 4 and 5 are long free-response questions that require about 25 minutes each to answer and are worth 13 points each. Show your work for each part in the space provided after that part.



1. An experiment is conducted in which Block A with a mass of m_A is slid to the right across a frictionless table. Block A collides with Block B, which is initially at rest, of an unknown mass and sticks to it.

   (a) Describe an experimental procedure that determines the velocities of the blocks before and after a collision. Include all the additional equipment you need. You may include a labeled diagram of your setup to help in your description. Indicate what measurements you would take and how you would take them. Include enough detail so that the experiment could be repeated with the procedure you provide.

   (b) If Block A has a mass of 0.5 kg and starts off with a speed of 1.5 m/s and the experiment is repeated, the velocity of the blocks after the collide are recorded to be 0.25 m/s. What is the mass of Block B ?

   (c) How much kinetic energy was lost in this collision from part (b)?

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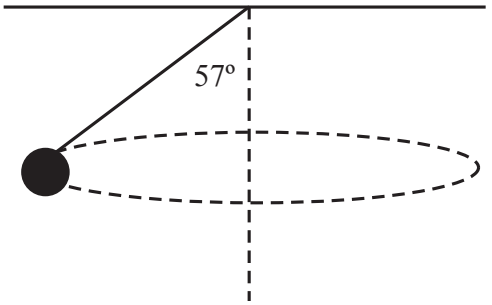

2. A conical pendulum is hanging from a string that is 2.2 meters long. It makes a horizontal circle. The mass of the ball at the end of the string is 0.5 kg.

(a) Below, make a free-body diagram for the ball at the point shown in the above illustration. Label each force with an appropriate letter.

(b) Write out Newton's Second Law in both the X and Y direction in terms used in your free-body diagram.

(c) Calculate the centripetal acceleration from your free-body diagram.

(d) What is the radius of the circle that the ball is traveling in?

(e) What is the speed of the ball?

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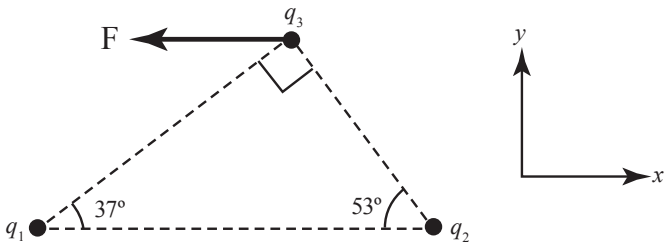
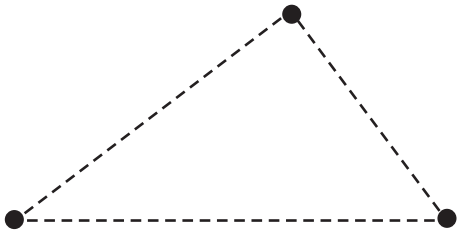


3. Three particles are fixed in place in a horizontal plane, as shown in the figure above. Particle 1 has a charge that has a magnitude of 4.0×10^{-6} C and the sign of the charge is unknown. Particle 2 has a charge that has a magnitude of 1.7×10^{-6} C and the sign of the charge is unknown. Particle 3 has a charge of $+1.0 \times 10^{-6}$ C. The distance between q_1 and q_2 is 5.0 m, the distance between q_2 and q_3 is 3.0 m, and the distance between q_1 and q_3 is 4.0 m. The electrostatic force **F** on particle 3 due to the other two charges is shown in the negative x-direction.

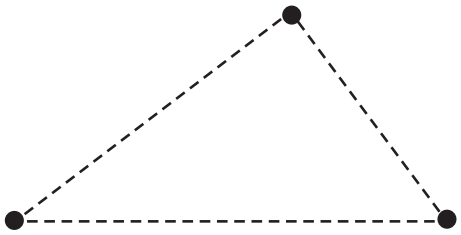
(a) Determine the signs of the charges of q_1 and q_2.

(b) On the diagram below, draw and label the force F_1 of the force exerted by Particle 1 on Particle 3 and the force F_2 of the force exerted by Particle 2 on Particle 3.



(c) Calculate the magnitude of the electrostatic force on particle 3.

(d) Draw and label clearly where another positively charged particle could be placed so the net electrostatic force on Particle 3 is zero.



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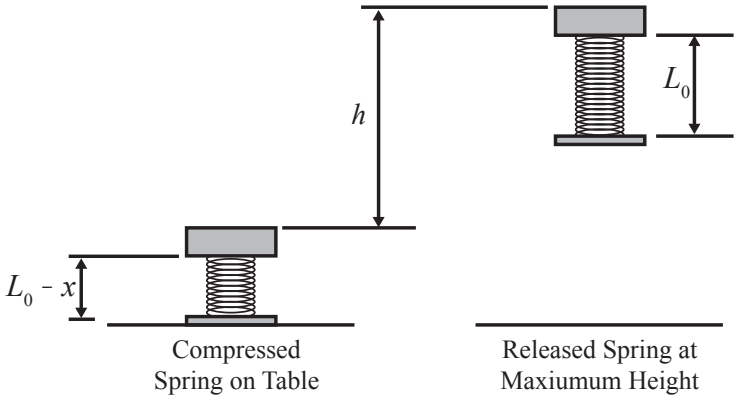

4 An experiment is designed to calculate spring constant k of a vertical spring for a jumping toy. The toy is compressed a distance of x from its natural length of L_0, as shown on the left in the diagram, and then released. When the toy is released, the top of the toy reaches a height of h in comparison to its previous height and the spring reaches its maximum extension. The experiment is repeated multiple times and replaced with different masses m attached to the spring. The spring itself has negligible mass.

(a) Derive an expression for the height h in terms of m, x, k, and any other constants provided in the formula sheet.

(b) To standardize the experiment, the compressed distance x is set to 0.020 m. The following table shows the data for different values of m.

	***m*(kg)**	***h*(m)**
	0.020	0.49
	0.030	0.34
	0.040	0.28
	0.050	0.19
	0.060	0.18

(i) What quantities should be graphed so that the slope of a best-fit straight line through the data points can help us calculate the spring constant k?

(ii) Fill in the blank column in the table above with calculated values. Also include a header with units.

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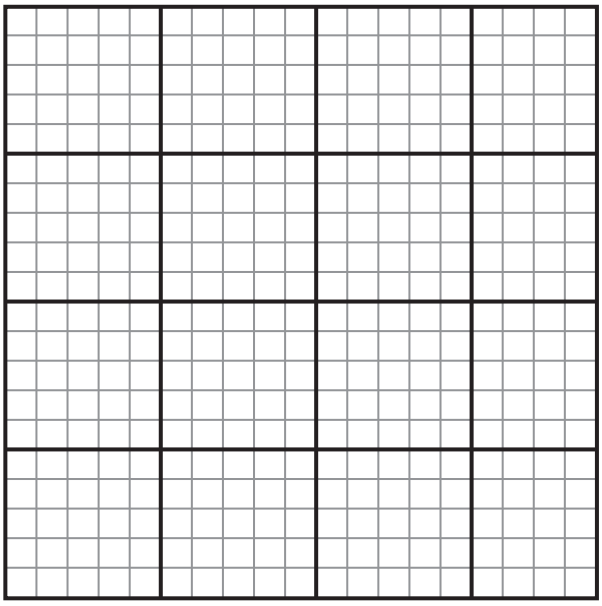
(c) On the axes below, plot the data and draw the best-fit straight line. Label the axes and indicate scale.



(d) Using your best-fit line, calculate the numerical value of the spring constant.

(e) Describe an experimental procedure that determines the height h in the experiment, given that the toy is only momentarily at that maximum height. You may include a labeled diagram of your setup to help in your description.

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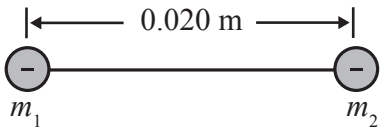

5. In the above diagram, two small objects, each with a charge of –4.0 nC, are held together by a 0.020 m length of insulating string. The objects are initially at rest on a horizontal, non-conducting, frictionless surface. The effects of gravity on each other can be considered negligible.

(a) Calculate the tension in the string.

(b) Illustrate the electric field by drawing electric field lines for the two objects on the following diagram.

The masses of the objects are $m_1 = 0.030$ kg and $m_2 = 0.060$ kg. The string is now cut

(c) Calculate the magnitude of the initial acceleration of each object.

(d) On the axes below, sketch a graph of the acceleration a of the object of mass m_2 versus the distance d between the objects after the string has been cut.

(e) In a brief paragraph, describe the speed of the objects as time increases, assuming that the objects remain on the horizontal, non-conducting frictionless surface.

STOP